Ground Current Investigation at Denmark, WI Residences

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Introduction

In October 2011, I was contacted by Jerome Hlinak of BCCRWE to investigate the possibility of a wind farm near Denmark, WI contributing to a "stray voltage"[1] problem affecting the health of area residents. I was informed that at least two families had moved out of their homes because they could no longer cope with the health problems they associated with their homes' electrical environments. In October 2011, I agreed to go to Denmark, WI and take measurements at several area homes.

This report, resulting from my work near Denmark, WI will provide 1) a brief history regarding the issue of ground currents/voltages, 2) information from published research on ground currents/voltages, and 3) data collected during my testing at area homes showing that a high frequency ground current/voltage issue is present.

History

In 1972 there was an oil embargo that forced countries to become more energy efficient. Energy efficient lightning, variable speed frequency drives, electronic motor starters, light dimmer switches, as well as a host of other electronic loads were rapidly being connected to the electrical grid. These devices use current in short pulses that create harmonics and high frequencies transients on the electrical circuits. Prior to this time the majority of the loads were linear loads. With Linear loads the current was drawn in a continuous manner. The electrical grid was designed for only 60-cycle linear loads like light bulbs and motors and not for the high frequency producing electronic loads that were being added rapidly after 1972. Most electric utilities have not updated their obsolete lines to handle the technological load that started being connected to their system in the late 70's and continues to date. The electric utility's primary neutral wire that was designed to bring the unbalanced current back to the substations was, and still is, no longer capable of handling the excess current and higher than 60-cycle currents now riding on the wire. The wire has too much impedance (opposition to AC current) due to its inadequate size, which causes overheating and a buildup of voltage on the wire called Primary Neutral to Earth Voltage (PNEV). The Institute of Electrical and Electronics Engineers (IEEE) recognized the problems caused by these changing loads and adopted a national standard, the IEEE-519, in 1981. The IEEE revised the standard in 1986, and again in 1992. It was a problem that was recognized and addressed by industry worldwide, except for most electric utilities. It became the topic of most power quality magazines and publications throughout the industry. For example, in the June 1999 issue of Electrical Construction and Maintenance (EC&M) Magazine, Ken Michaels wrote, "Harmonics: It surfaced as a buzzword in the early 1980's, …".

From the IEEE (1996) *Guide for Applying Harmonic Limits on Power Systems*:

[1] The term "stray voltage" was coined by electric utilities and public utilities commissions. The word "stray" infers that no one is responsible. There may be stray dogs and stray cats; it may be unknown where they come from or where they are going. Voltage, on the other hand, does not stray; it is governed by scientific laws (Ohm's Law, Kirchhoff's Law, etc.) and it goes where people put it. Therefore, in this report we will refer to this problem as ground currents/voltages, and not "stray voltage".

> When single phase electronic loads are supplied with a 3-phase, 4-wire circuit, there is a concern for the current magnitudes in the neutral conductor. Neutral current loading in the 3-phase circuits with linear loads is simply a function of the load balance among the three phases. With relatively balanced circuits, the neutral current magnitude is quite small. This has resulted in a practice of under sizing the neutral conductor in relation to the phase conductors.
>
> With electronic loads supplied by switch-mode power supplies, the harmonic components in the load currents can result in much higher neutral current magnitudes. This is because the odd triplen harmonics (3, 9, 15, etc.) produced by these loads show up as zero sequence components for balanced circuits. Instead of canceling in the neutral (as is the case with positive and negative sequence components), zero sequence components add together in the neutral conductor. The third harmonic is usually the largest single harmonic component in single phase power supplies or electronic ballasts. (p. 63)

Glen A. Mazur, in his 1992 technical manual *Power Quality Measurement and Troubleshooting*, stated:

> Triplen harmonics do not cancel, but add together in the neutral conductor. In systems with many 1-phase nonlinear loads, neutral current can exceed an individual phase current. Generally, the amount of neutral current is between 125% and 225% of the highest phase current. The third harmonic current is usually responsible for most of the neutral current because the third harmonic typically represents the harmonic with the highest current value. High neutral current is dangerous because it causes overheating in the neutral. Because there is no CB in the neutral conductor to limit current, as in the phase conductors (A, B, and C), overheating of the neutral can become a fire hazard.

Because of the increased and higher frequency currents on the utilities' primary neutral, the electric utilities decided to use the earth as a return path to their substations for the excess currents they are responsible for. Once the currents are in the earth, they flow uncontrolled over the surface, across private property, into homes and barns, and through humans and animals. This was done despite national standards and electrical safety codes, as evidenced in the IEEE's *National Electrical Safety Code* book under Rule 92D, which states, "Ground connection points shall be arranged so that under normal circumstances there will be no objectionable flow of current over the grounding conductor" (1996, p. 16).

Also regarding objectionable flow of current, the IEEE's *NESC Handbook, Fourth Edition* (1996) tells us that:

> Such flow may be disturbing to the service, as is sometimes the case around dairy barns in which cows are connected to milking systems. …installations near areas that are often known to present specific problems (such as milking barns without adequate voltage gradient control, pipelines, electric railways, conduits, etc.) may need special attention to limit damage to equipment or uncomfortable conditions for personnel or animals. (p. 30)

In 1991, the United States Department of Agriculture (USDA) published a report entitled "Effects of Electrical Voltage/Current on Farm Animals". Within this report is a section on the electrical power system of the United States, which tells us:

> The U.S. electrical power system is a huge network and is based on a specific transmission, distribution, and utilization philosophy. When consumer equipment consisted primarily of lights, motors, and tube-type electronic equipment, and electrical loads were relatively small, neutral-to earth voltages and transients were not great problems, due to the lower neutral currents and the tolerance of the equipment. With increasing use of low-signal-level solid-state computers and microprocessors, increasing electrification and automation of farms, and increased loads on distribution lines, the issue of power quality and tolerable neutral-to-earth voltage is becoming increasingly important. It will become necessary in the future to more clearly specify the power characteristics that the utility is to provide at the delivery point, the limits to which a consumer's type of usage can he allowed to affect other customers and the utility, and who is to monitor and require conformance to the specifications. The ramifications of meeting these needs are that difficult economic, technical, and legal problems will arise and will have to be solved. (p. 6-2)

A subsequent section on electrical system load growth says:

> The increase in neutral currents and leakage or uncleared fault currents to earth due to electrical load growth…along a distribution line can lead to an increase in the neutral-to-earth voltage. (p. 6-3)

It should be noted that the electric utilities did not create the high frequencies present on their distribution lines due to consumer load growth. The manufacture and use of electronic equipment created the problem, and the electric utilities inherited it. However, the electric utilities are responsible for what is on their lines and for putting the current into the earth, thus allowing currents to flow uncontrolled over the earth's surface. To reiterate – from the first footnote in this report – the term "stray voltage" was coined by electric utilities and public utilities commissions. The word "stray" infers that no one is responsible. There may be stray dogs and stray cats; it may be unknown where they come from or where they are going. Voltage, on the other hand, does not stray; it is governed by scientific laws (Ohm's Law, Kirchhoff's Law, etc.) and it goes where people put it.

Initial Observations and Testing

After arriving in Denmark, WI, I met with Jerome Hlinak and another representative, who escorted me to 6 local residences where they had arranged for me to conduct testing. These local residents believe their families' health problems are directly related to the operation of recently energized wind turbines.

Relying on my extensive experience with diagnosing and troubleshooting electrical problems, and power quality issues in particular, I expected to find distorted 60 cycle sine waves riddled with high frequency transients and harmonics during my testing in the Denmark, WI area. This was, in fact, the case with every measurement I collected, whether from connection points at an area home's kitchen sink to kitchen floor, at utility primary neutral to earth voltage to a remote ground rod, or between two remote ground rods in a resident's yard.

The issue affecting these Denmark, WI area residents is that of high frequency ground currents/voltages, known to many as "stray voltage", or, more properly, electrical pollution (in the case of electrical equipment) and electrical poisoning (in the case of humans and animals). Electrical and electronics engineering societies, utilities, governments, and many other organizations have researched this issue for decades, and trade publications and newspaper articles have addressed this issue for more than the past decade.

Marek Samotyj, EPRI's (Electrical Power Research Institute) manager for power quality stated in a July 5, 1999 *Fortune* magazine article, "Hot New Technologies for American Factories", "[t]he quality situation will get worse before we will be able to mitigate it . . . One reason is that EPRI [Electrical Power Research Institute] expects 70% of all electricity produced within the U.S. to flow through electronic devices by 2002, vs. 30% today" (Bylinski, p. 4)

An article by Beck Ireland in the September 2006 edition of EC&M, "Clearing up Confusion on Unwanted Voltages", highlights numerous incidents of "stray voltages" affecting humans, animals, and electric utilities, including:

- East Village, NY, 2004: Jodie S. Lane, a 30-year-old Columbia University graduate student, was killed when she stepped on a metal plate.
- Feb 12, 2006: Four people shocked by service box near Port Authority Bus Terminal.
- Feb 17, 2006: Dog electrocuted on patch of concrete in Park Slope Brooklyn
- March 2006: Nine-year old boy hospitalized after an electric jolt while walking over a metal plate in Harlem.
- March 2006: New York City's Consolidated Edison found 1,214 instances of stray voltage during a year-long examination of electrical equipment on city streets.
- Con Ed expects to spend $100 million this year [2006] toward reducing the risk of stray voltage.

More recent evidence of this issue can be found in a *Toronto Sun* newspaper article, "Children Shocked by Stray Voltage", where Don Peat reports, "Several children shocked by stray voltage – just two weeks after a second dog was electrocuted – has finally prompted Toronto Hydro to mobilize 600 workers to inspect its aging street-level infrastructure" (January 30, 2009).

The issue of ground current has been addressed not only in consumer publications, but also in electrical industry engineering manuals, code books and other published guidelines. For example, the *Wiley Encyclopedia of Electrical and Electronics Engineering, Volume 8* (1999), states, "It is an unsafe practice to allow current to flow over the earth continuously, uncontrolled. All continuously flowing current must be contained within insulated electrical conductors". Also, in a 2006 white paper "BC Hydro Deals With Farm Neutral to Earth Voltage", David M. Rogers, an Agricultural Specialist for BC Hydro, states:

> The Canadian Electrical Code Rule 10-200 states that concerning "The Rule (for grounding and bonding conductors) does not intend there be current flowing through the bonding and grounding system during normal operation." Its Subrule (3) of Chapter 10-200 states that: "Where by using multiple grounds objectionable flow of current occurs over the grounding conductor:
>
> - One or more of the grounds shall be abandoned;
> - The location of the grounds shall be changed;
> - The continuity of the conductor between the grounding connections shall be suitably interrupted;
> - Other effective action shall be taken to limit the current." (p.3)

According to Rogers (2006), BC Hydro has developed a positive approach to dealing with the issue of ground currents/voltages, ultimately producing positive results for both Canadian farmers and BC Hydro, including, 1) a reduction in mastitis in farms at any one time from 230 in 1997 to fewer than 20 in the period from 2003 to 2006, and, 2) never having had a legal suit over farm ground current/voltage issues (p. 13).

With regard to wind turbines contributing to ground currents/voltages, I will offer this information. IEEE Std. 519-1992 states:

> The emergence of renewable, alternate energy sources has resulted in the use of many varied topologies as power conditioners or inverters for utility tied operation. These inverters are available in single-phase units and in three-phase units, and their outputs may be very clean sinusoids with near unity power factor or may contain various characteristic and noncharacteristic harmonics and power factors that may cause unacceptable power quality on the electric utility grid or interfere with its controls or relays. (p. 23)

To summarize, this issue has been well-publicized and well-documented.

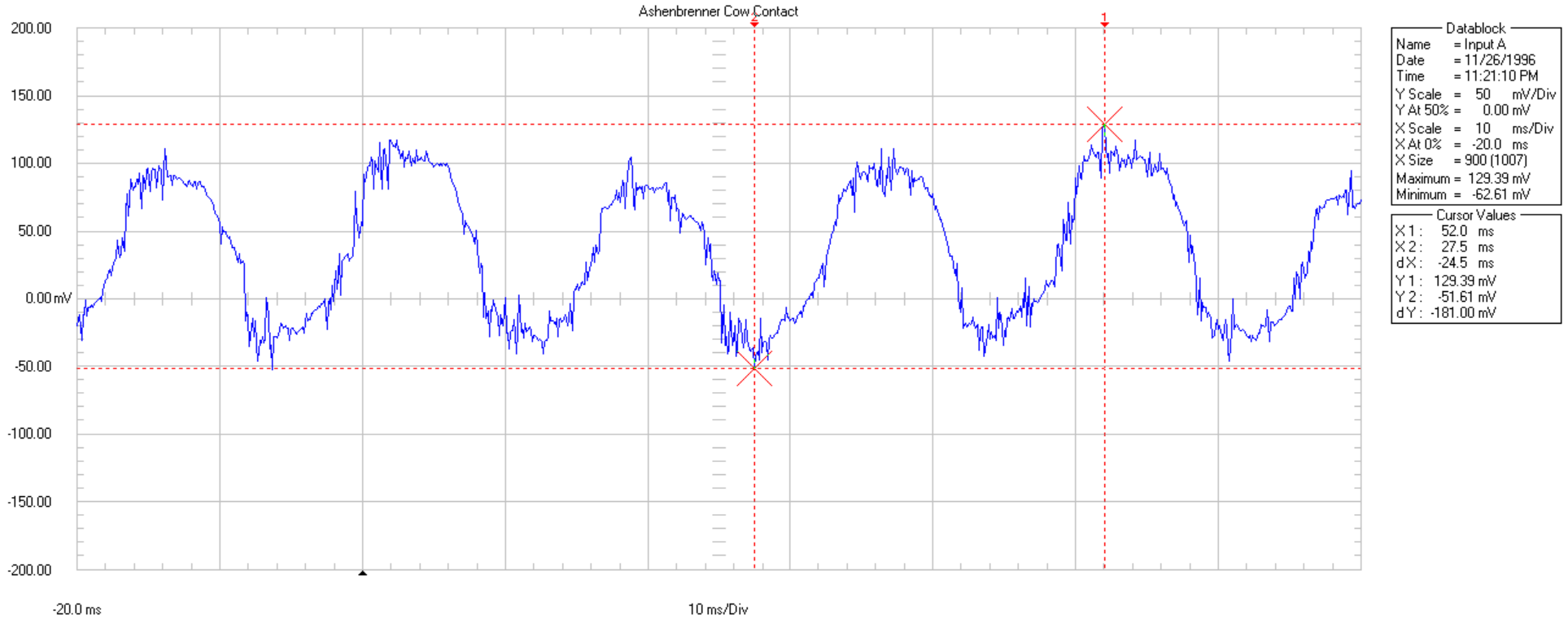
After my initial meeting with Jerome, we proceeded to several (6) Denmark, WI area homes to conduct testing. At each home I used a Fluke 199 two-channel Scopemeter to collect readings from 1) kitchen sink to kitchen floor and 2) utility primary neutral to earth voltage (PNEV) from the nearest utility down ground. When PNEV was unavailable for measurement, readings were collected from 2 remote ground rods placed in the resident's yard. The measurement results are presented below following a brief commentary.

My research into the issue of ground currents/voltages, spanning more than the past decade, has allowed me to gather a vast library of information in the form of books, industry publications and codes,

peer-reviewed journal articles, scientific experiments, etc. I will provide here a few pertinent statements to keep in mind while reviewing the following data.

1) Frequencies above 1.7 kHz dissipate internally to the human body (Reilly, 1992).
    - Frequency spectrums of the collected waveforms show that residents in these locations are exposed to frequencies well in excess of 1.7 kHz.
2) "…the absolute (as well as the modest) level of contact current modeled (18 uA) produces average electric fields in tissues along its path that exceed 1mV/m. At and above this level, the NIEHS Working Group [1998] accepts that biological effects relevant to cancer have been reported in numerous well-programmed studies" (Kavet, 2000).
    - Analysis of collected waveforms indicates that residents in test locations are exposed to anywhere from 16 to 291 times this amount of current.
3) Symptoms of Microwave and Radio-Frequency Radiation (excerpted from NMRI, 1972)
    - Headaches
    - Heart Palpitations/Arrhythmia
    - Fatigue
    - Muscle spasms
    - Weakness
    - Insomnia
    - Digestive problems
    - Anxiety
    - Depression
    - Altered sugar metabolisms (Diabetes)
    - Sinusitis
    - Nausea
    - Deteriorating Vision
    - Difficulty concentrating
    - Memory Loss
    - Muscle & joint pain
    - Breathing Difficulties

Ashenbrenner

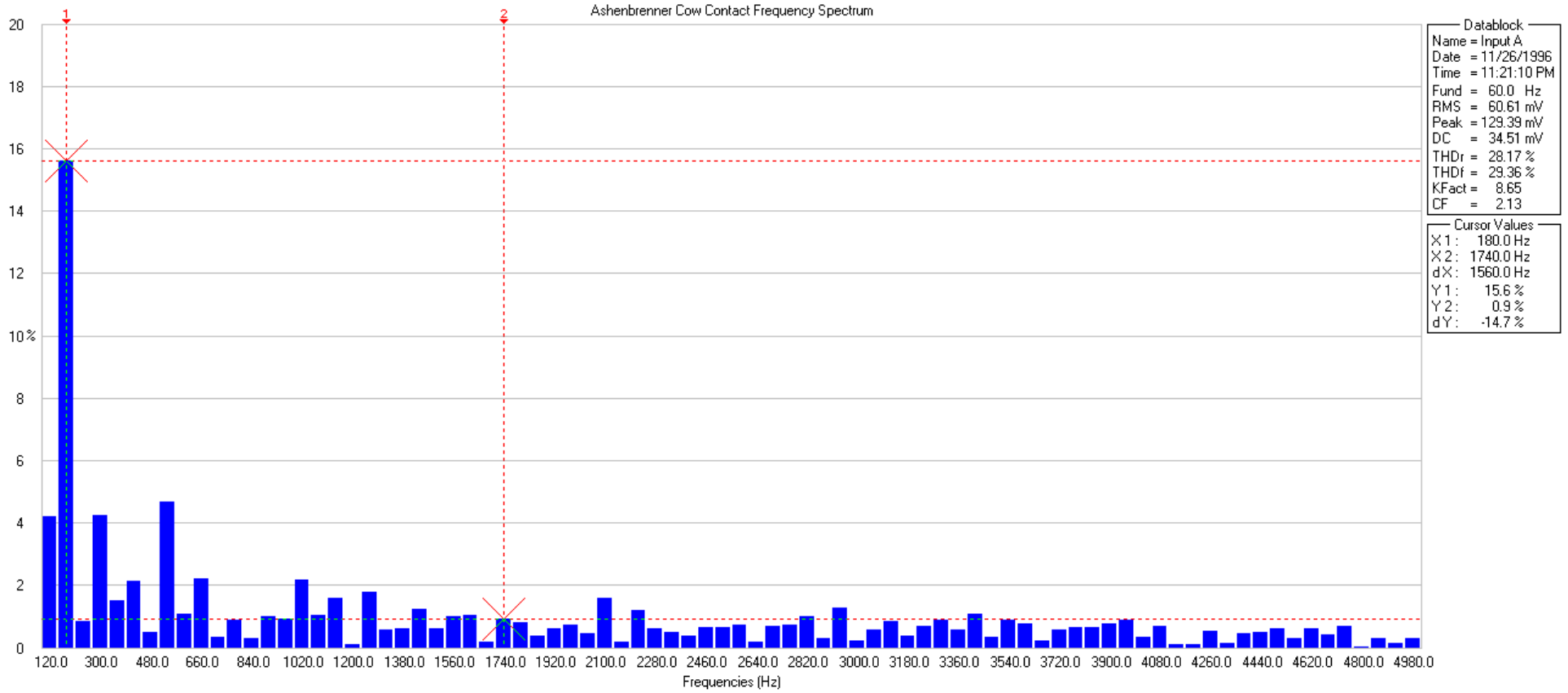


The waveform was collected with a Fluke 199 Scopemeter at the Kevin Ashenbrenner farm. Leads were connected between a 19 square inch stainless steel plate and the water pipe (cow contact). The voltage displayed on the above waveform is 181 mV.

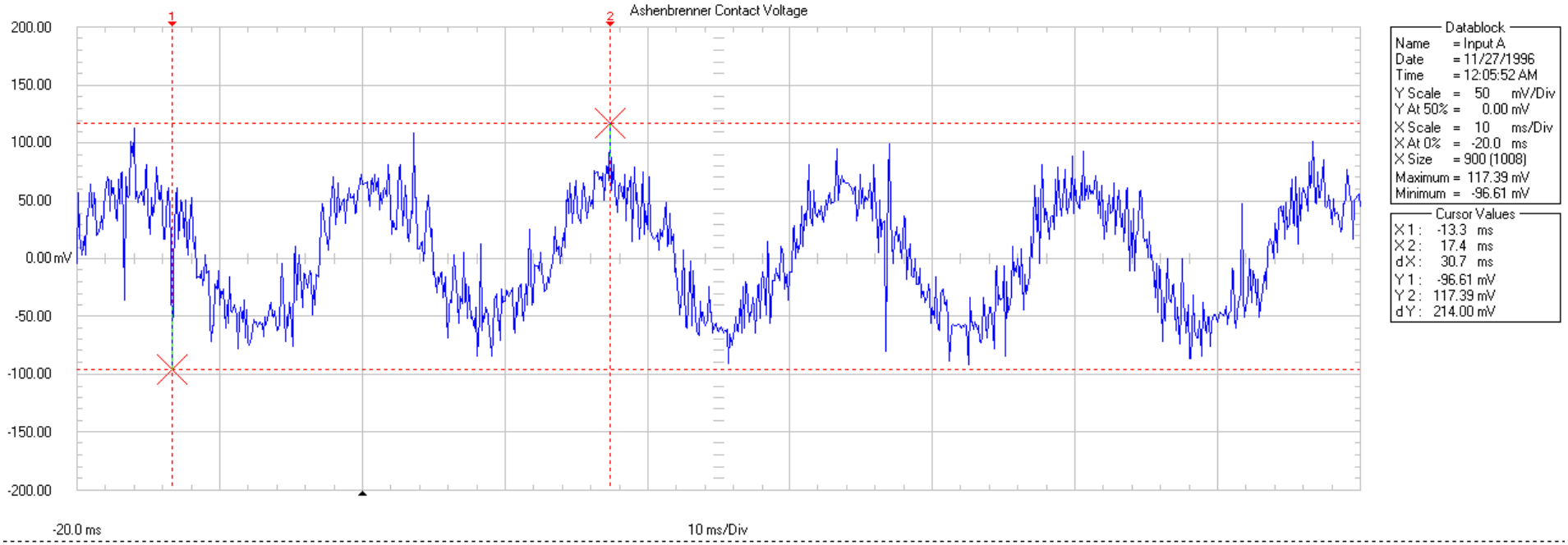
"… a potential difference between front and hind hooves of a dairy cow, much less than the often quoted threshold value of 0.5 V, when applied for long periods of time, could possibly affect cow health and milk production. Values as low as approximately 10 mV could conceivably be significant" (Polk, 2001).

"…we estimated that a front-to-rear hoof step potential exposure of 0.002 to 0.02 volts would produce such field strengths in the cow's leg muscle tissue" (Final Report of the Science Advisors to the Minnesota Public Utilities Commission, 1998).

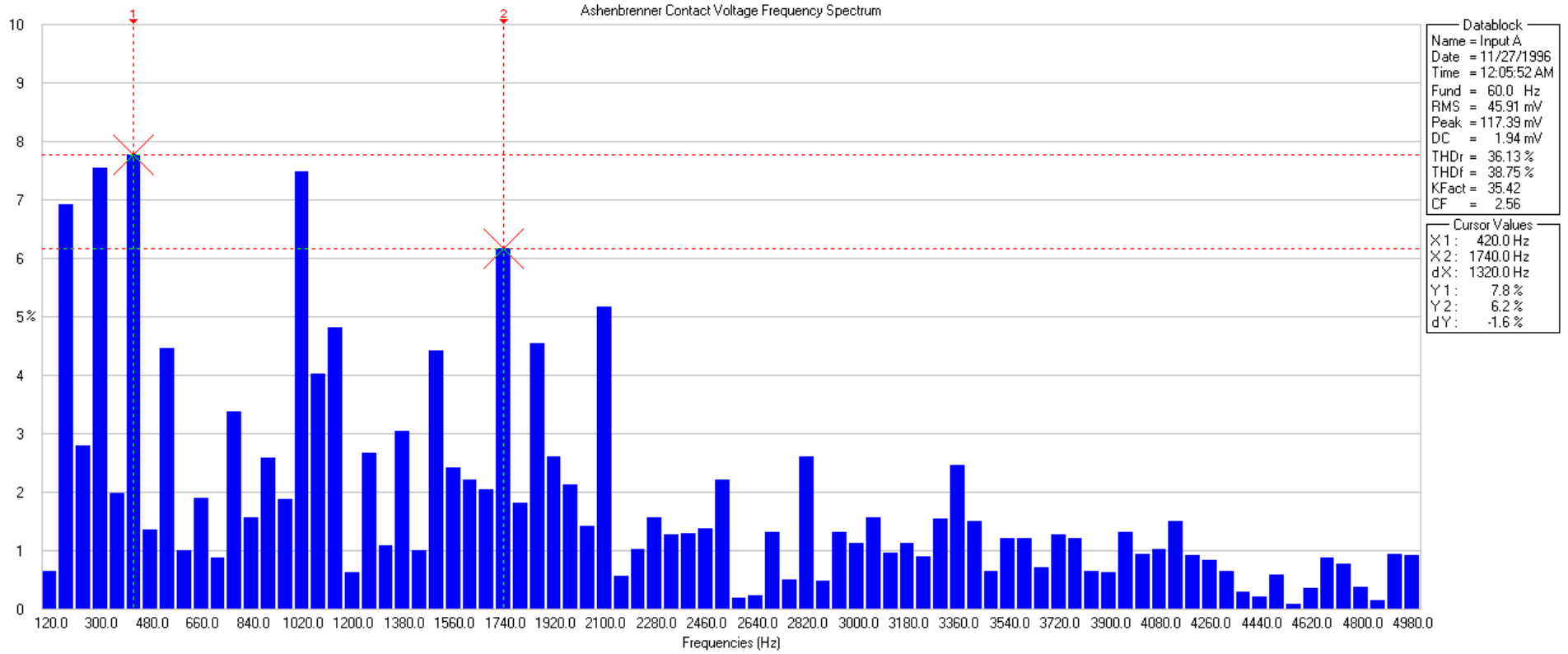
"Exposure to E&MF (on) resulted in an average decrease of 4.97, 13.78, and 16.39% in milk yield, fat corrected milk yield, and milk fat, respectively; and an increase of 4.75% in dry matter intake" (Burchard, Monardes, & Nguyen, 2003).



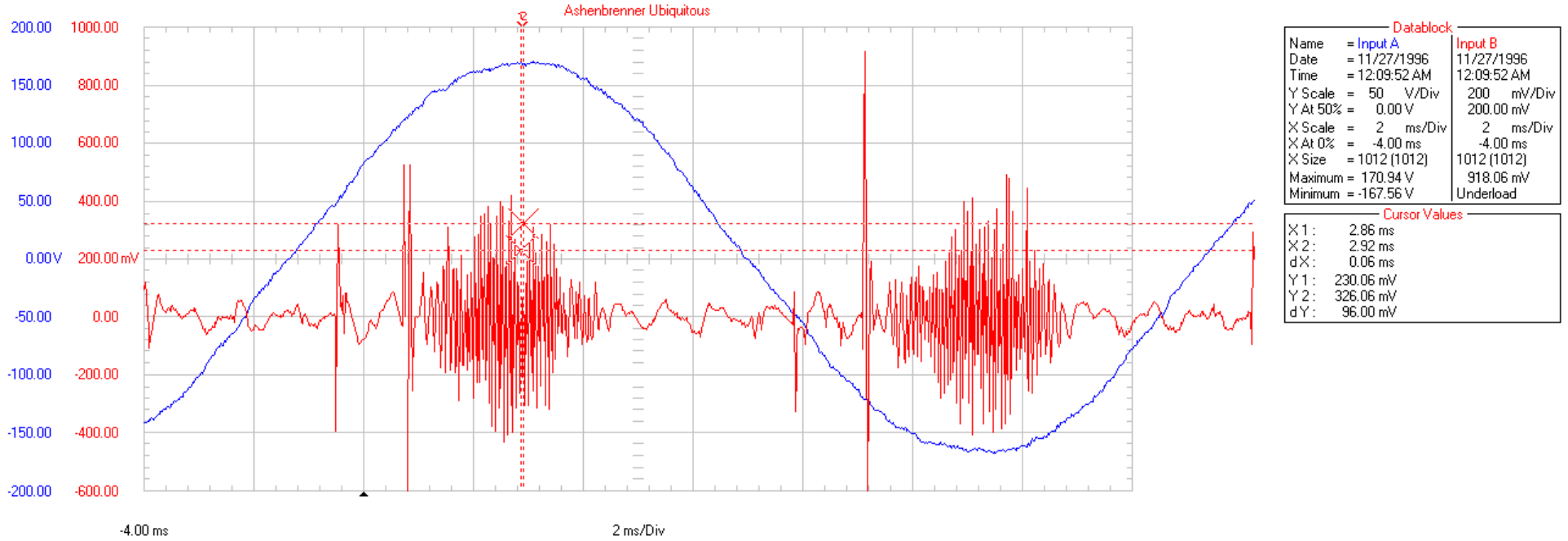
The frequency specrtum is of the cow a cow contact voltage waveform collected in the barn of Kevin Ashenbrenner, near Denmark WI.



The waveform was collected with a Fluke 199 Scopemeter at the Kevin Ashenbrenner home. The leads were connected betweeen the kitchen sink and an EKG patch placed on the floor. (Contact Voltage) Assuming a person has an impedance of 500 Ohms, the contact current would be 428 micro amperes or more than 23 times the current the NIEHS states is relevant to cancer.

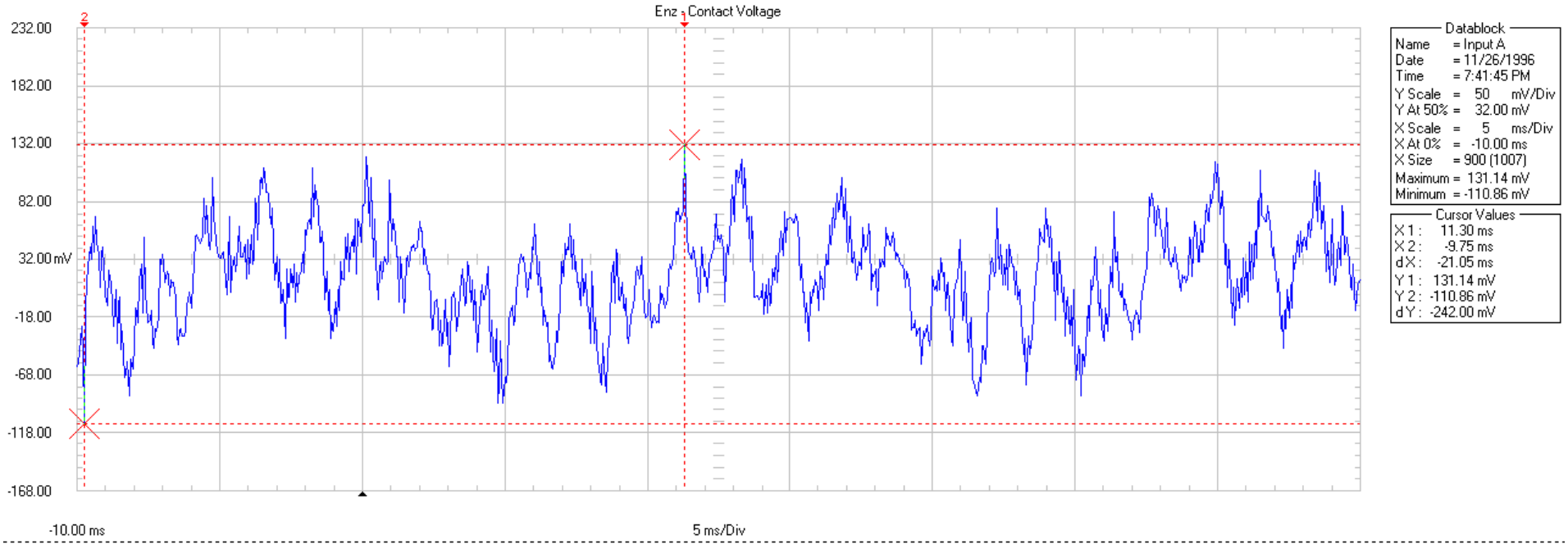


The above frequency spectrum is of a waveform collected between the sink and floor (contact Voltage) at the Kevin Ashenbrenner home near Denmark, WI.

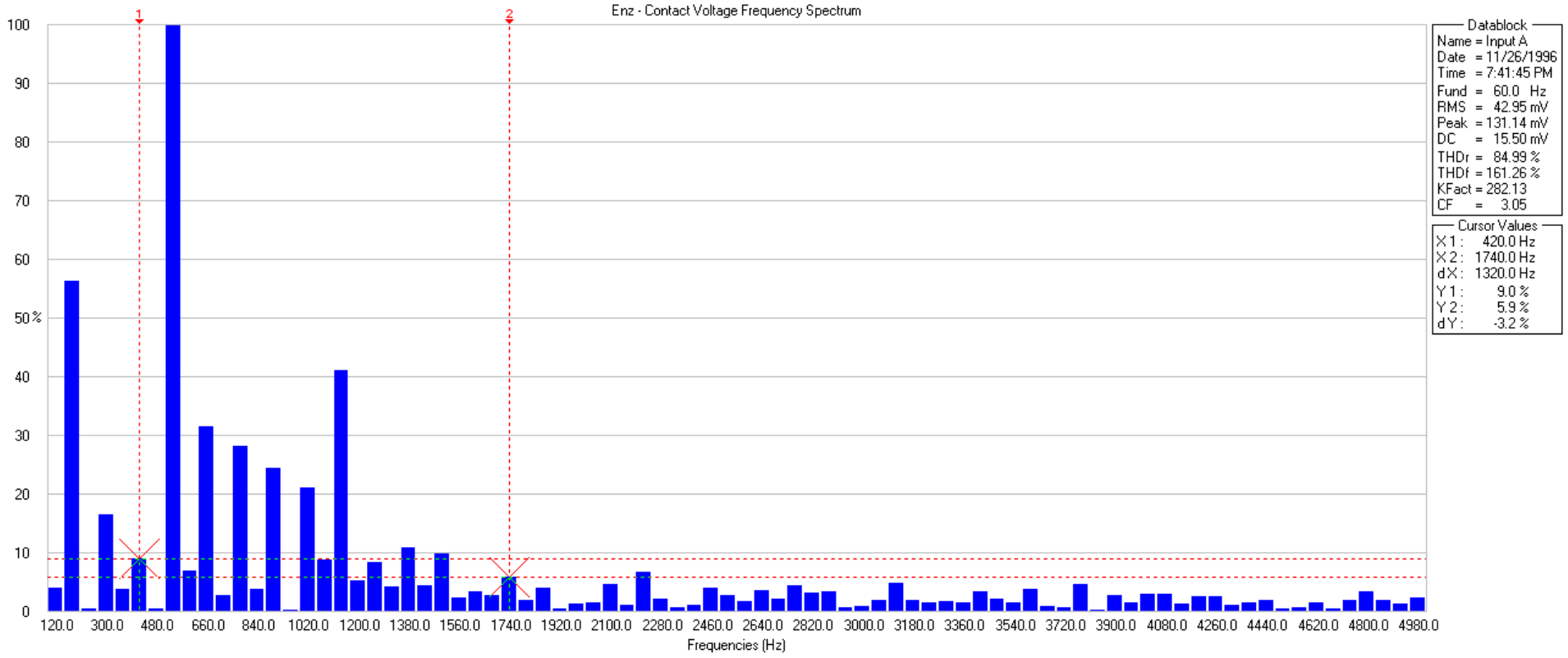


The waveform was collected with a Fluke 199 Scopemeter at the Kevin Ashenbrenner home. Channel A was connected to a 120V receptacle. Channel B was connected at the same potential except through the Graham ubiquitous filter (removes the 60 cycle). The area between the cursors represents a frequency of 16.6 kHz. The high frequency is riding on the utility supplied 60 cycle waveform.

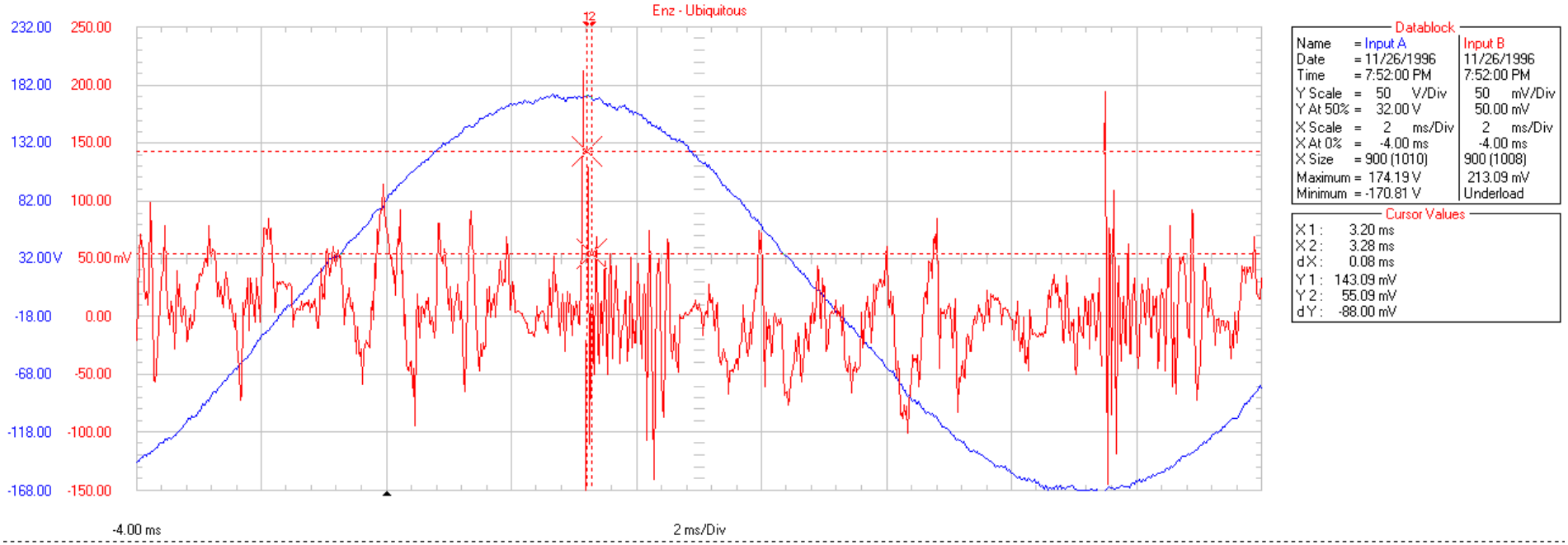
Enz



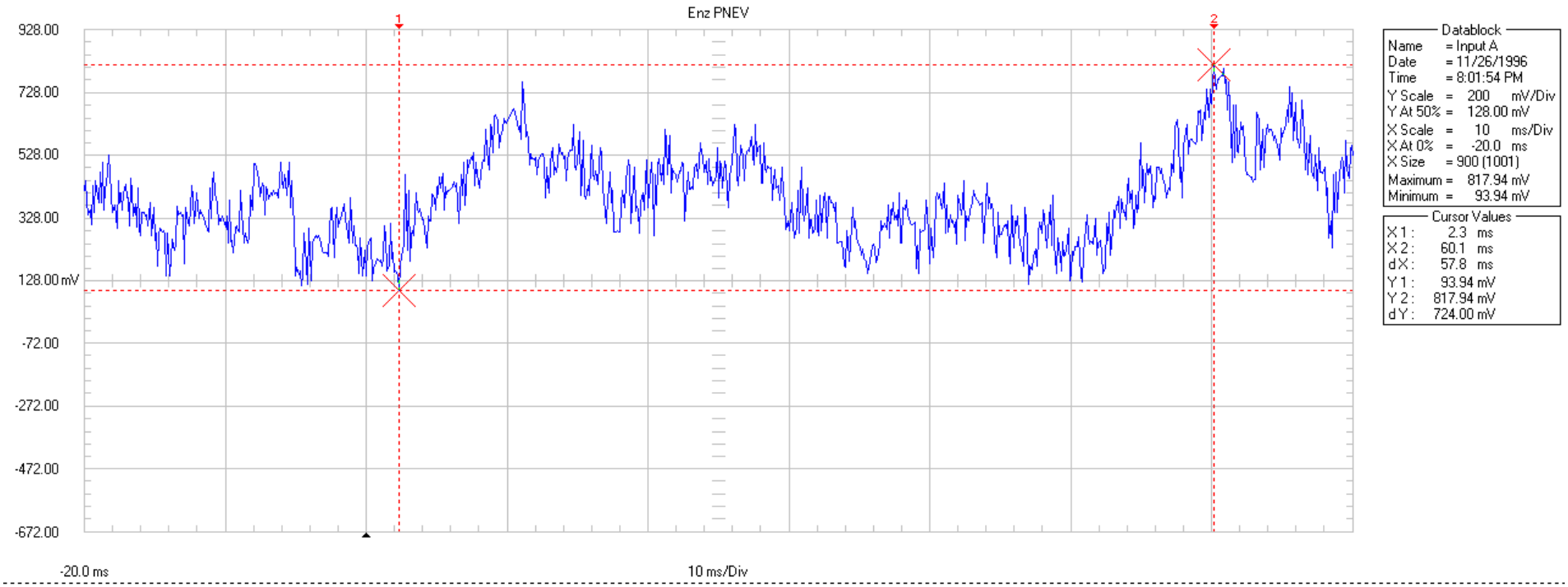
The waveform was collected with a Fluke 199 Scopemeter at the Dave and Rosemary Enz home. The leads were connected betweeen the kitchen sink and an EKG patch placed on the floor. (Contact Voltage) Assuming a person has an impedance of 500 Ohms, the contact current would be 484 micro amperes or more than 26 times the current the NIEHS states is relevant to cancer.



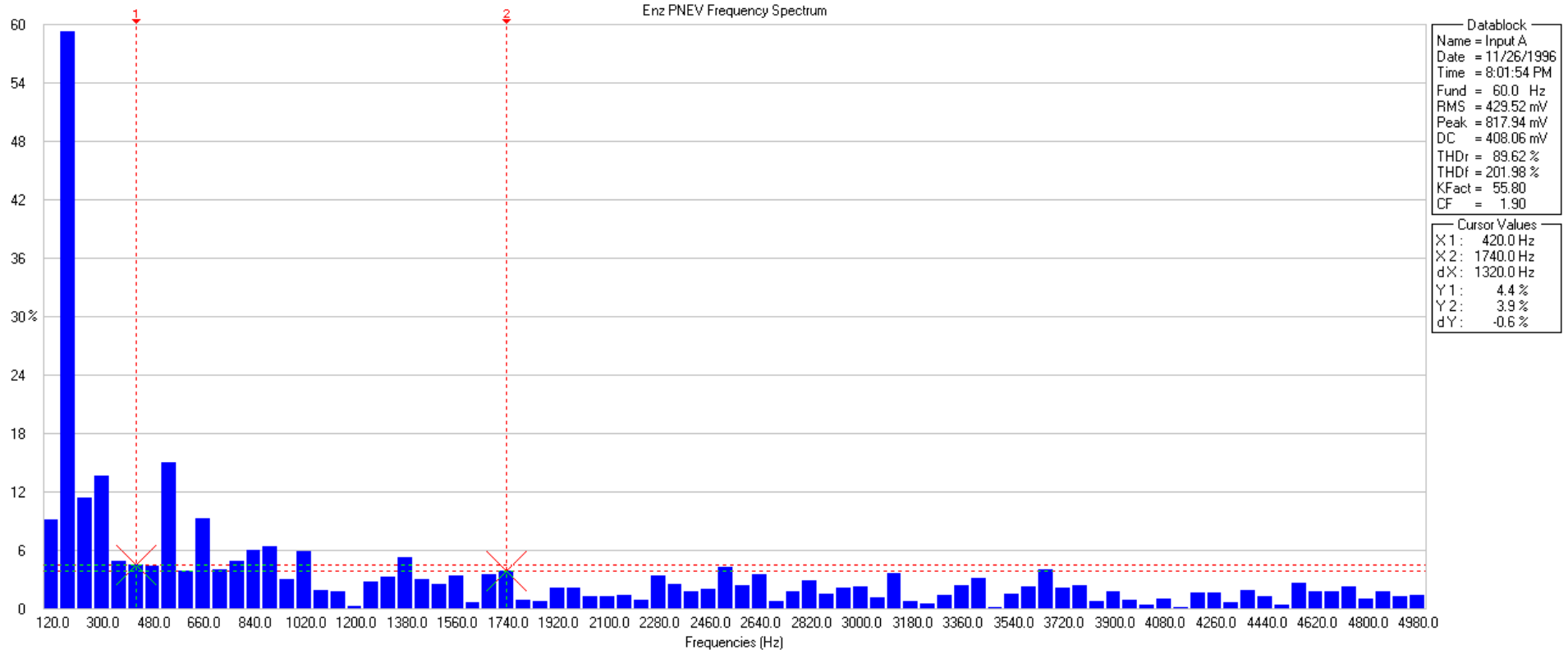
The above frequency spectrum is of a waveform collected between the sink and floor (contact Voltage) at the Dave and Rosemary Enz home near Denmark, WI.



The waveform was collected with a Fluke 199 Scopemeter at the Dave and Rosemary Enz home. Channel A was connected to a 120V receptacle. Channel B was connected at the same potential except through the Graham ubiquitous filter (removes the 60 cycle). The area between the cursors represents a frequency of 12.5 kHz. The high frequency is riding on the utility supplied 60 cycle waveform.

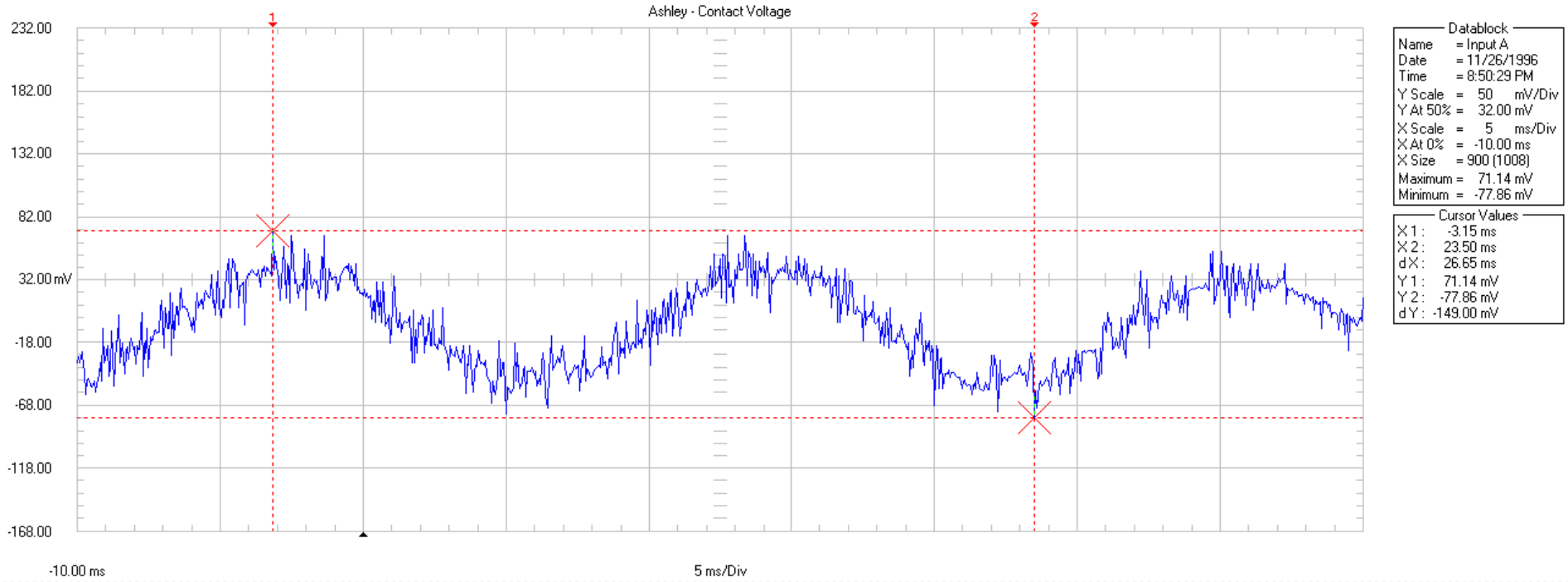


The distorted waveform was measured with a Fluke 199 Scopemeter at PNEV at the transformer down ground across the road from the Enz home near Denmark, WI. One lead was connected to the utlityprimary down ground and the other to a remote ground rod. The windturbines were running in close proximity to the measurement points.



The above frequency spectrum is of a waveform collected at primary neutral to earth voltage at the transformer down ground across the road from the Dave and Rosemary Enz home near Denmark, WI.

Ashley



The waveform was collected with a Fluke 199 Scopemeter at the Ashley home. The leads were connected betweeen the kitchen sink and an EKG patch placed on the floor. (Contact Voltage) Assuming a person has an impedance of 500 Ohms, the contact current would be 298 micro amperes or more than 16 times the current the NIEHS states is relevant to cancer.

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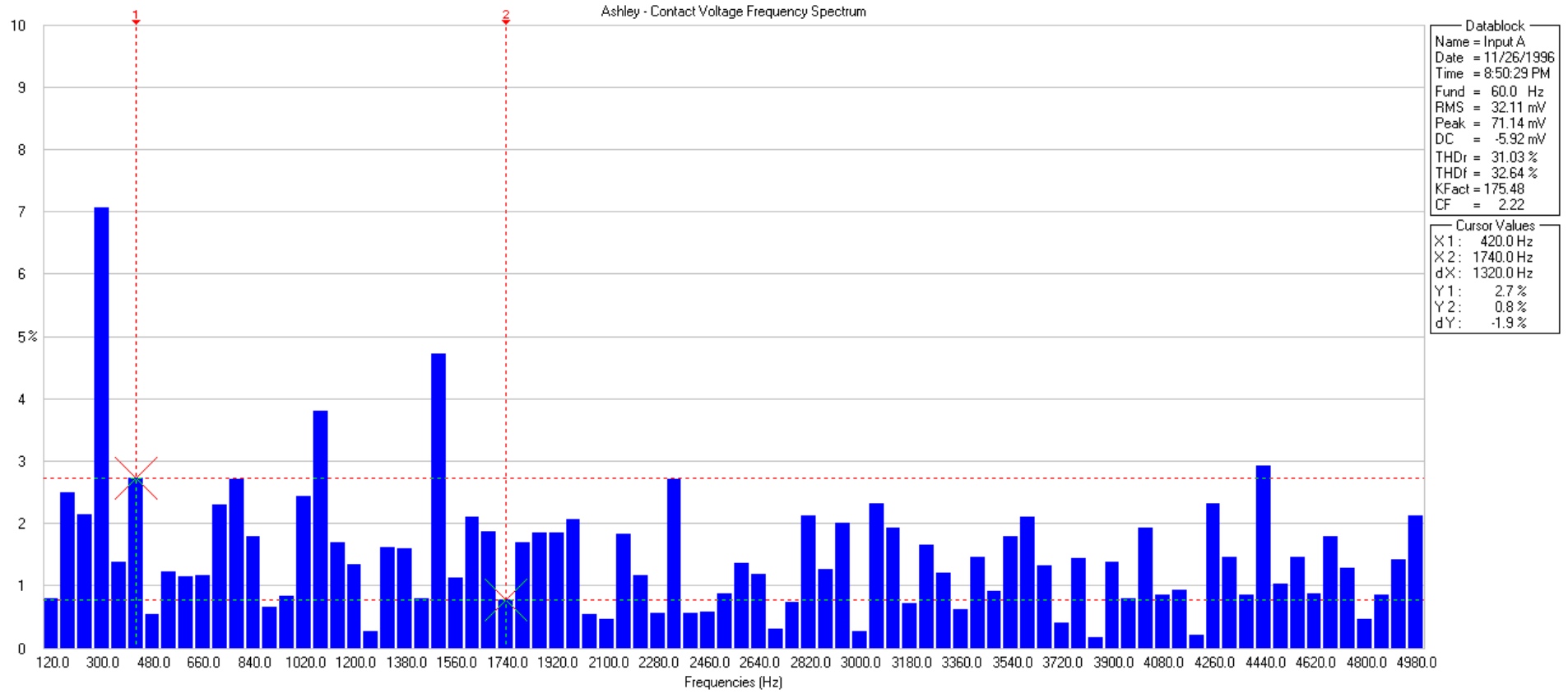
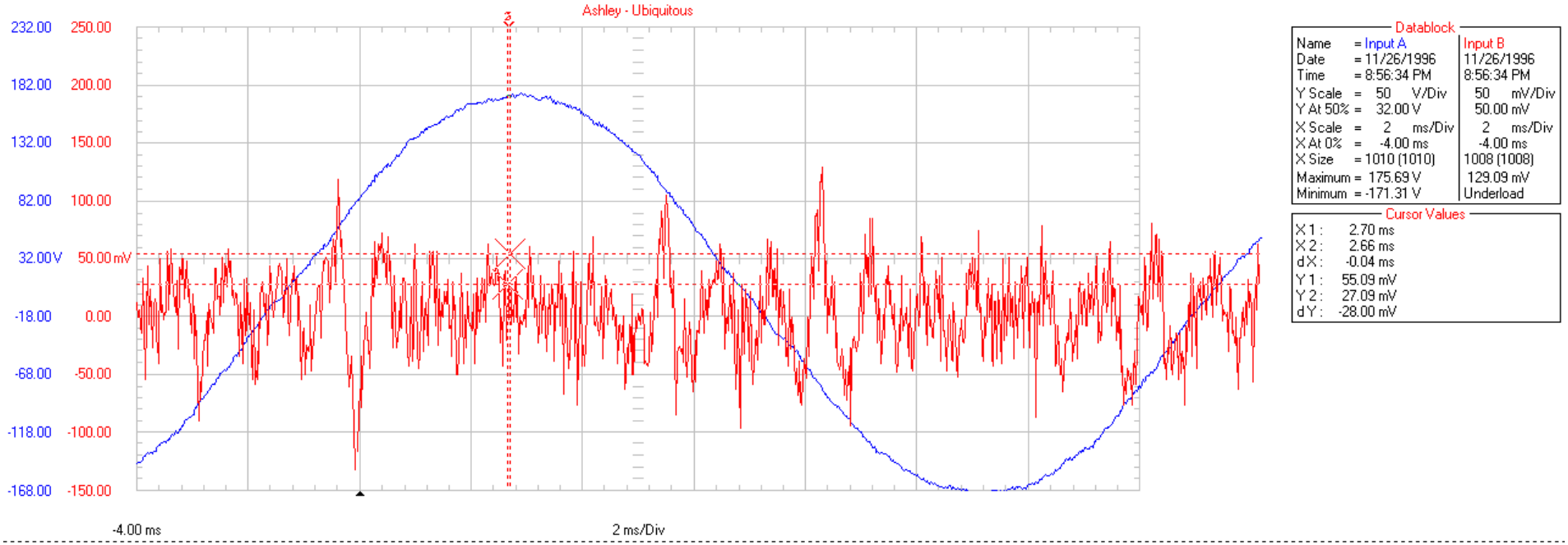
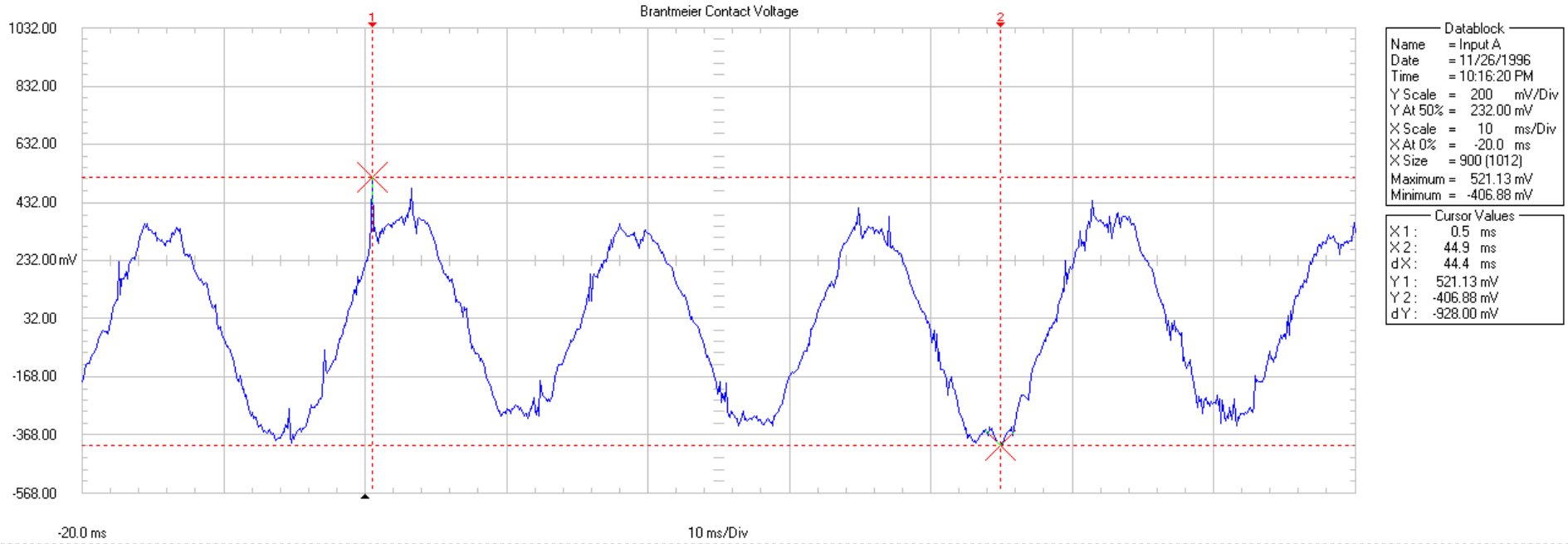


The above frequency spectrum is of a waveform collected between the sink and floor (contact Voltage) at the Ashley home near Denmark, WI.

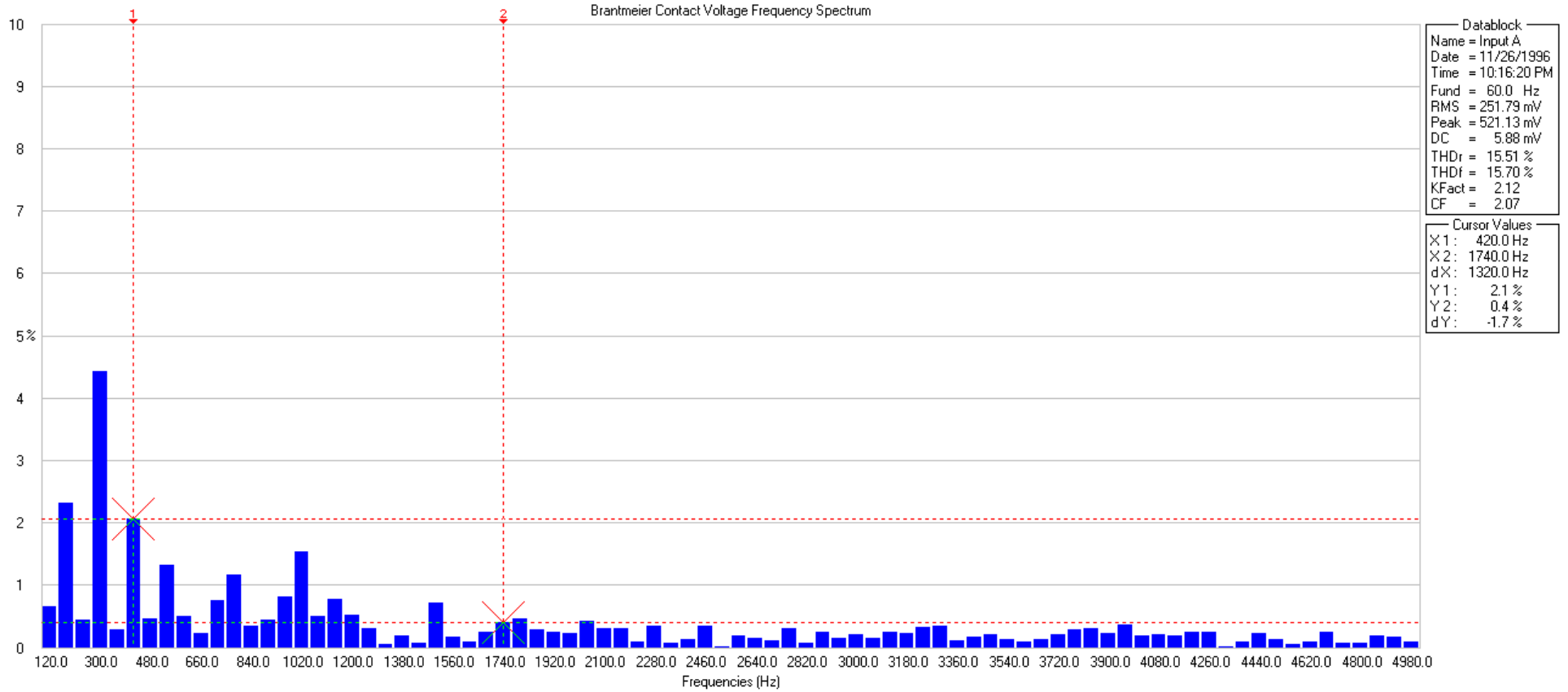


The waveform was collected with a Fluke 199 Scopemeter at the Ashley home. Channel A was connected to a 120V receptacle. Channel B was connected to the same potential except through a Graham ubiquitous filter (removes the 60 cycle). The area between the cursors represents a frequency of 25 kHz. The high frequency is riding on the utility supplied 60 cycle waveform.

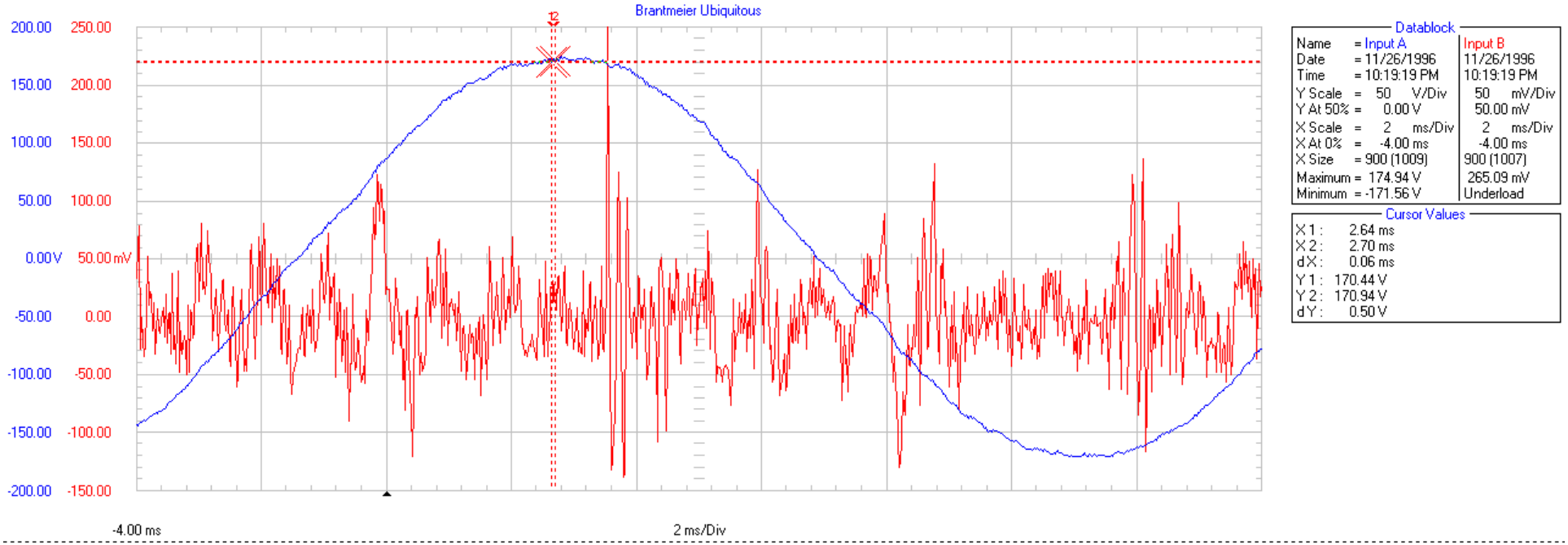
Brantmeier



The waveform was collected with a Fluke 199 Scopemeter at the Mark and Tammy Brantmeier home. The leads were connected betweeen the kitchen sink and an EKG patch placed on the floor. (Contact Voltage) Assuming a person has an impedance of 500 Ohms, the contact current would be 1856 micro amperes or more than 103 times the current the NIEHS states is relevant to cancer.

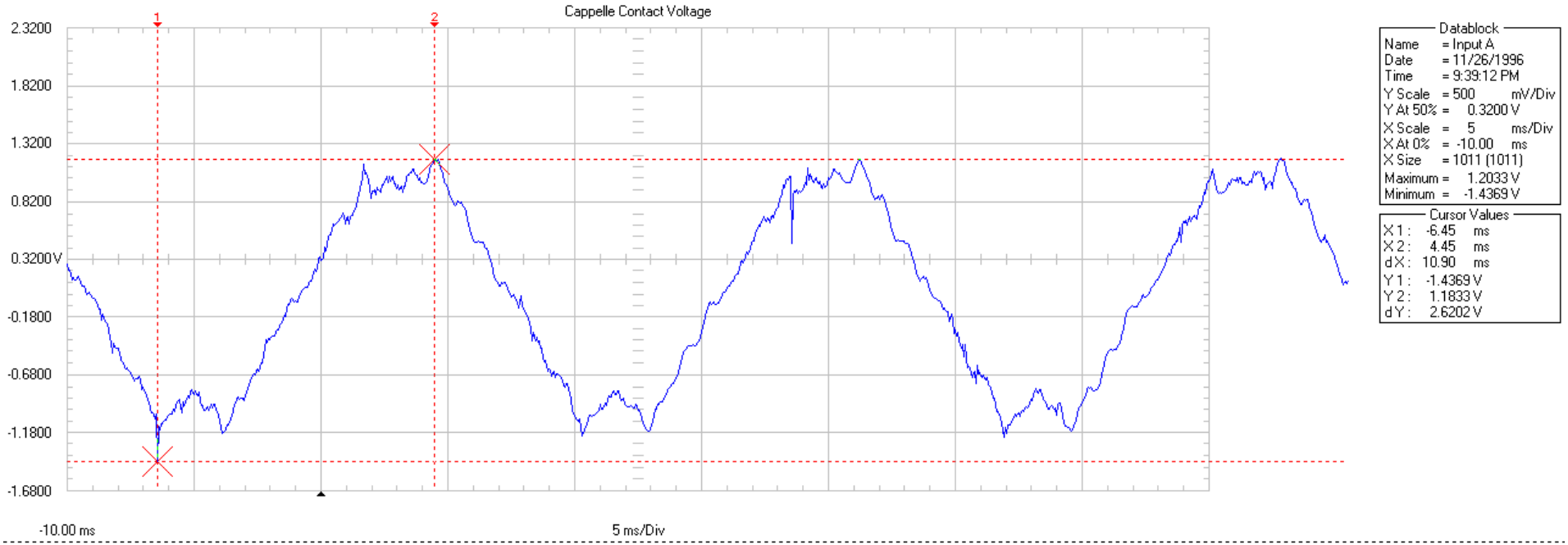


The above frequency spectrum is of a waveform collected between the sink and floor (contact Voltage) at the Brantmeier home near Denmark, WI.

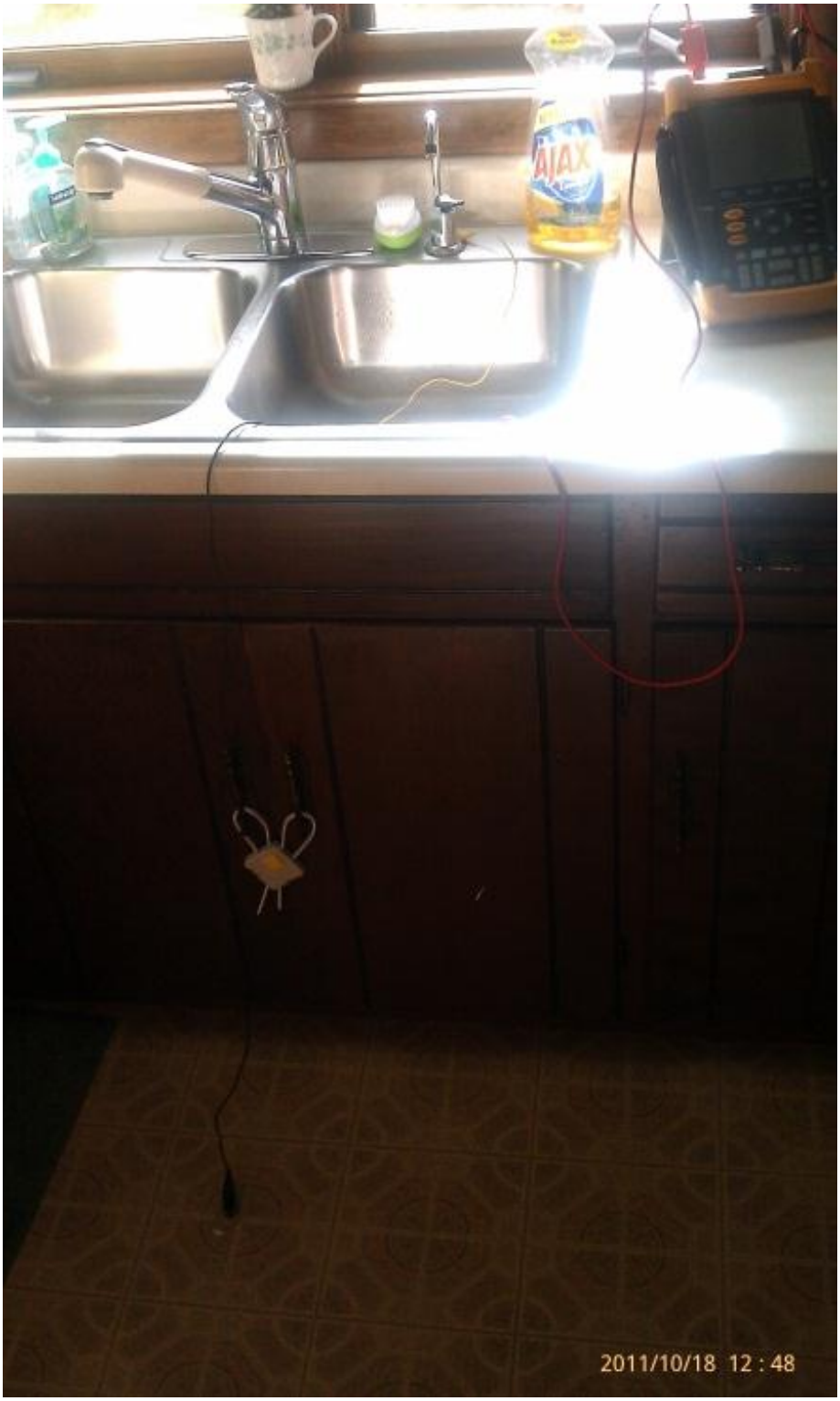


The waveform was collected with a Fluke 199 Scopemeter at the Mark and Tammy Brantmeier home. Channel A was connected to a 120V receptacle. Channel B was connected at the same potential except through the Graham ubiquitous filter (removes the 60 cycle). The area between the cursors represents a frequency of 16.6 kHz. The high frequency is riding on the utility supplied 60 cycle waveform.

Cappelle



The waveform was collected with a Fluke 199 Scopemeter at the Darrel and Sarah Cappelle home. The leads were connected betweeen the kitchen sink and an EKG patch placed on the floor. (Contact Voltage) Assuming a person has an impedance of 500 Ohms, the contact current would be 5,240 micro amperes or more than 291 times the current the NIEHS states is relevant to cancer.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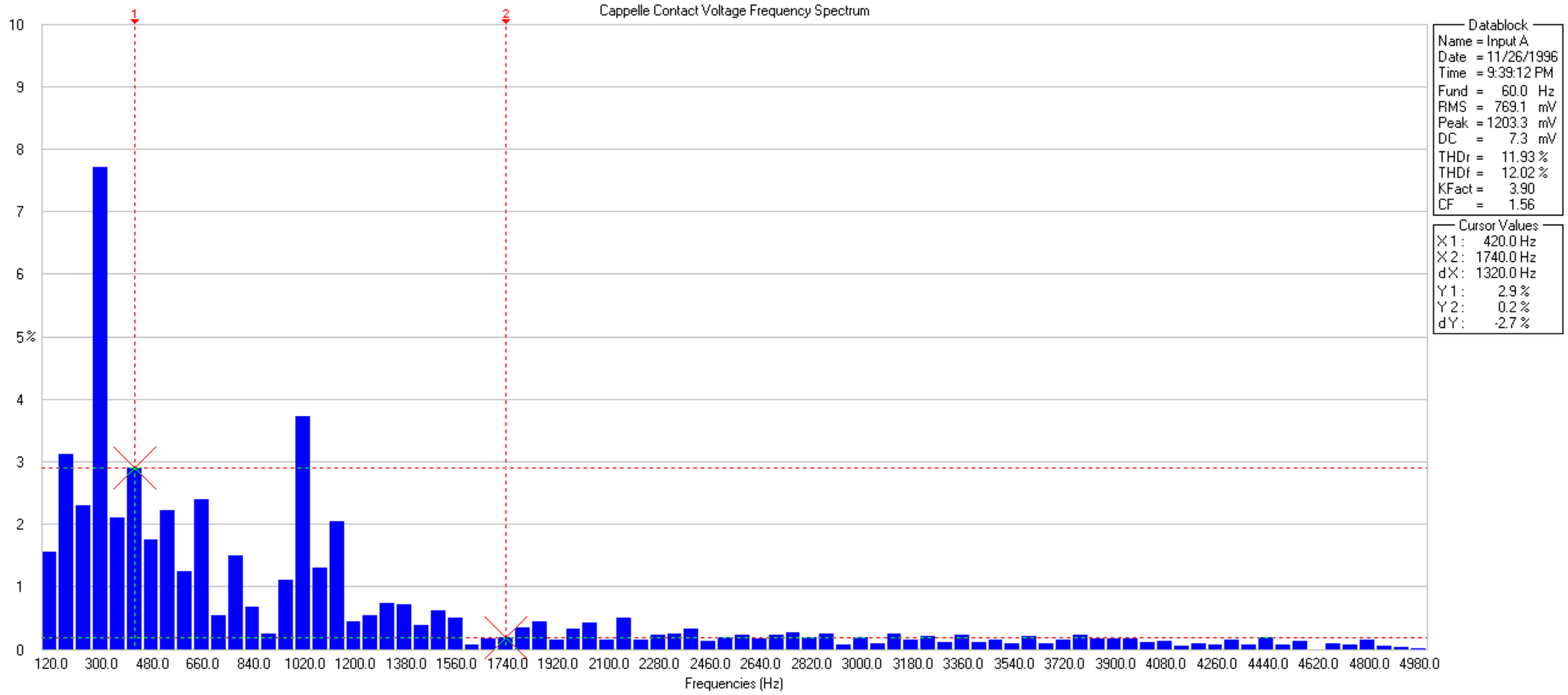
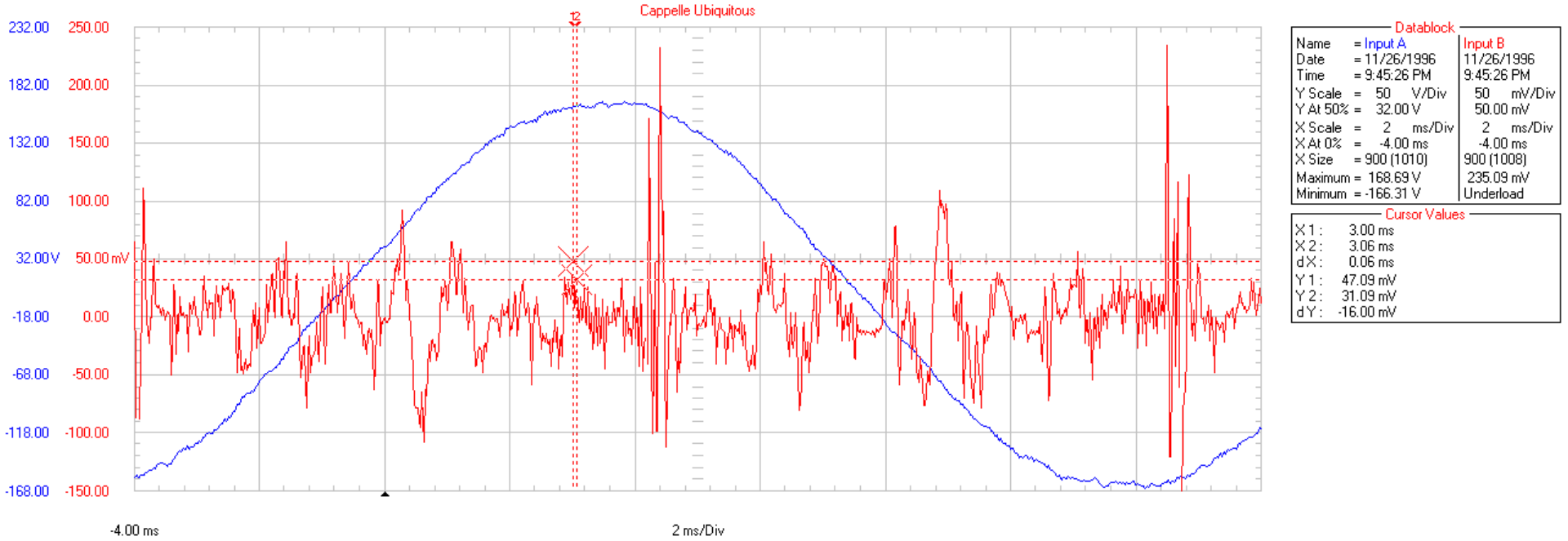
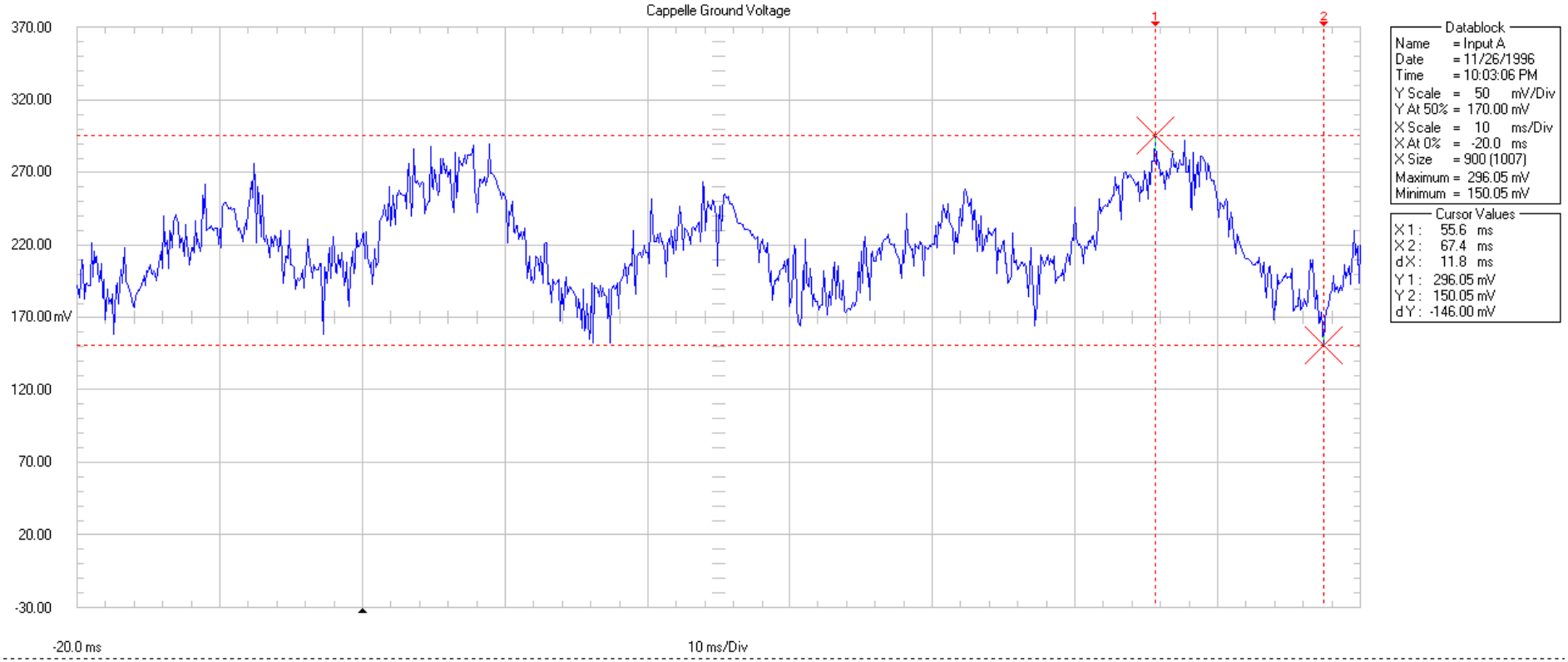


The above frequency spectrum is of a waveform collected between the sink and floor (contact Voltage) at the Cappelle home near Denmark, WI.



The waveform was collected with a Fluke 199 Scopemeter at the Darrel and Sarah Cappelle home. Channel A was connected to a 120V receptacle. ChannelB was connected at the same potential except through the Graham ubiquitous filter (removes the 60 cycle). The area between the cursors represents a frequency of 16.60kHz. The high frequency is riding on the utility supplied 60 cycle waveform.



The distorted waveform was measured with a Fluke 199 Scopemeter. The leads were connected between two remote ground rods in the yard of Darrel and Sarah Cappelle.

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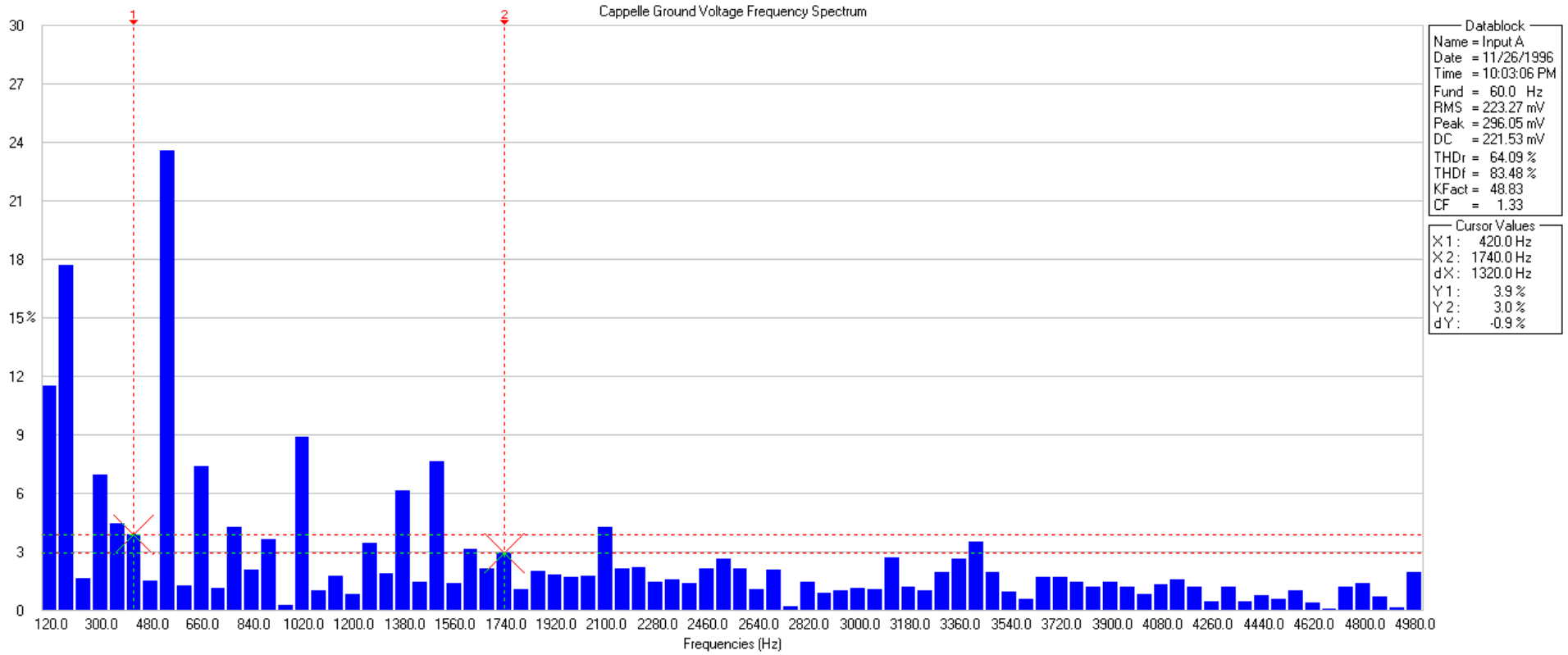
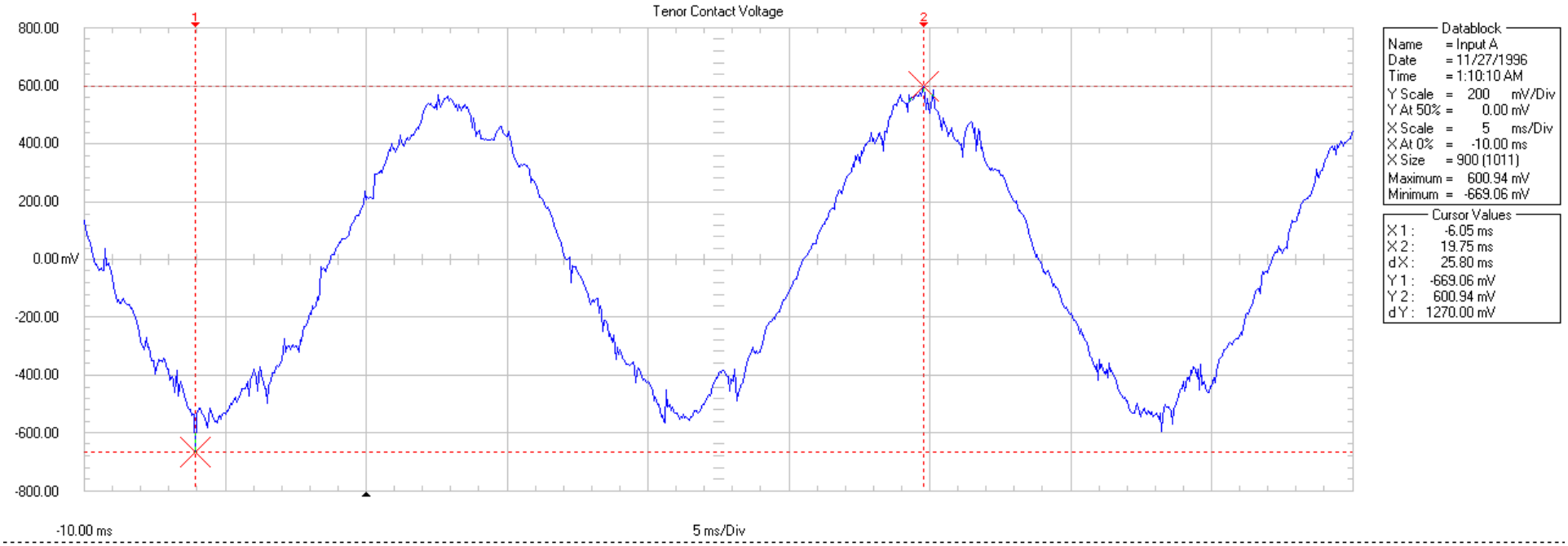
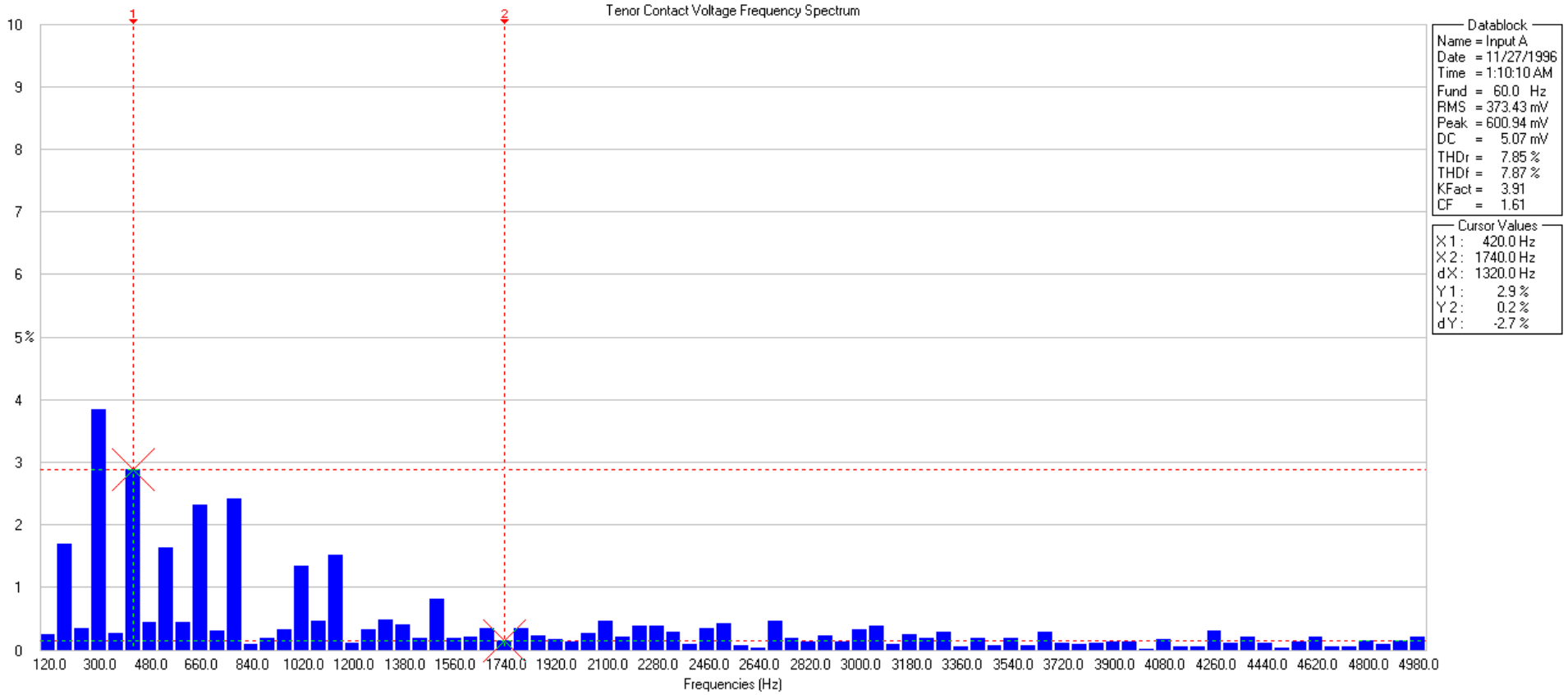


The above frequency spectrum is of a waveform collected between two remote ground rods in the yard of the Darrel and Sarah Cappelle home near Denmark, WI.

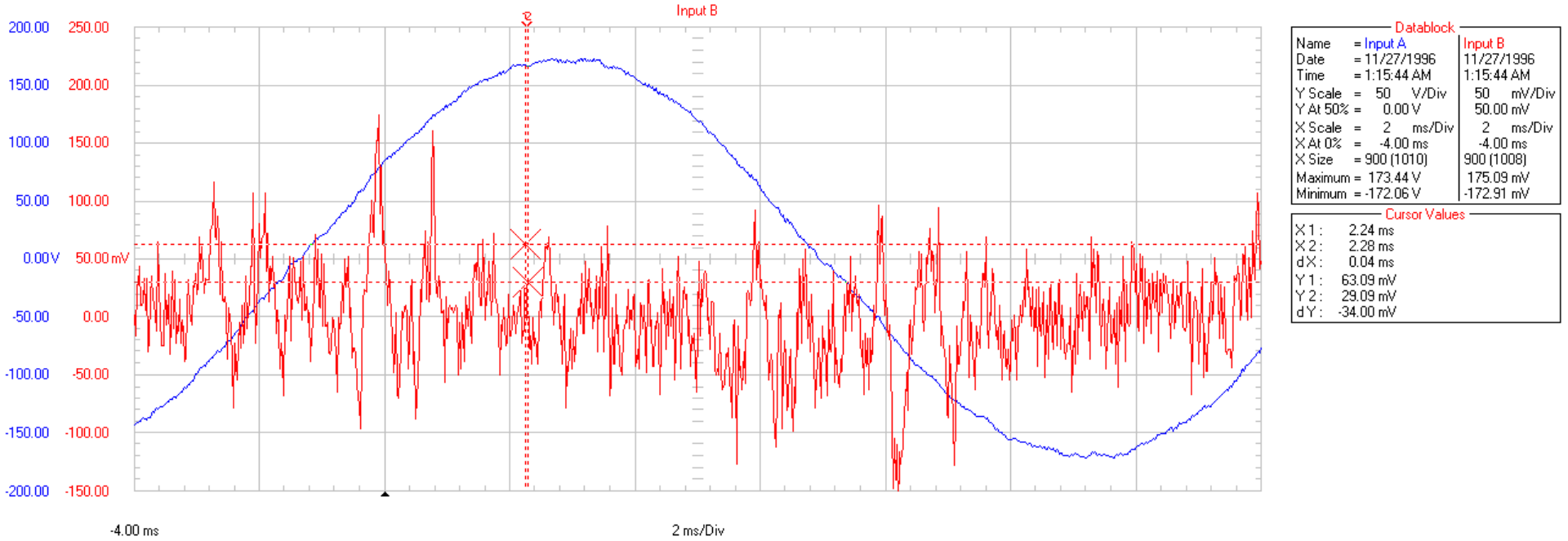
Tenor



The waveform was collected with a Fluke 199 Scopemeter at the Jean and Larry Tenor home. The leads were connected betweeen the kitchen sink and an EKG patch placed on the floor. (Contact Voltage) Assuming a person has an impedance of 500 Ohms, the contact current would be 2,540 micro amperes or more than 141 times the current the NIEHS states is relevant to cancer.



The above frequency spectrum is of a waveform collected between the sink and floor (contact Voltage) at the Tenor home near Denmark, WI.



The waveform was collected with a Fluke 199 Scopemeter at the Jean and Larry Tenor home. Channel A was connected to a 120V receptacle. Channel B was connected at the same potential except through the Graham ubiquitous filter (removes the 60 cycle). The area between the cursors represents a frequency of 25kHz. The high frequency is riding on the utility supplied 60 cycle waveform.

Summary

The data collected was the data present at the time of collection. It needs to be understood that these levels change with time and electrical usage. Several wind turbines were in operation at the time of testing. Long-term monitoring should be done while the wind turbines are in operation and also when they are not in operation. The data should then be compared to determine what contributions (of high frequency transients and harmonics) are attributable to the turbines.

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